P25032.A06

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: G. FINKELSHTAIN et al. Conf. No. 9110

Serial No: 10/796,305 Group Art Unit: 1795

Filed: March 10, 2004 Examiner: R. Alejandro

For : SELF-CONTAINED FUEL CELL AND CARTRIDGE THEREFOR

COVER LETTER REGARDING EXECUTED RULE 1.131 DECLARATION

Commissioner for Patents
U.S. Patent and Trademark Office
Customer Service Window, Mail Stop
Randolph Building
401 Dulany Street
Alexandria, VA 22314
Sir:

The undersigned points out that the executed Rule 1.131 Declaration being filed herewith includes copies of pages 1, 3 and 4 of an executed Declaration forwarded to the law firm of the undersigned by facsimile from the Inventors, and page 2 of the Rule 1.131 Declaration along with all of the pages of Exhibit A, which were added by the law firm of the undersigned, and which are identical to pages 1-4 of the Rule 1.131 Declaration (including Exhibit A) forwarded to the Inventors for execution.

Further, the law firm of the undersigned has been advised that the Inventors reviewed all pages of the Rule 1.131 (including all pages of Exhibit A) before executing the Rule 1.131 Declaration.

Accordingly, Applicant respectfully submits that the present Rule 1.131 Declaration is properly executed and should be considered as filed in executed form.

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Should there be any questions regarding this paper, please contact the undersigned at the below-listed number.

Respectfully submitted, G. FINKELSHTAIN et al.

Neil F. Greenblum

Reg. No. 28,394 Stephen M. Roylance

Reg. No. 31,296

May 19, 2008 GREENBLUM & BERNSTEIN, P.L.C. 1950 Roland Clarke Place Reston, VA 20191 (703) 716-1191 P25032.D01 Serial No.: 10/796,305

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DECLARATION UNDER 37 C.F.R. 1.131

Sir:

We, Gennadi Finkelshtain, Mark Estrin and Rami Hashimshony, do hereby declare:

- 1. We are the inventors of the subject matter disclosed and recited in at least independent claims 1, 39 and 93 of the above-identified application.
- 2. We completed the invention of at least claims 1, 39 and 93 (and those claims dependent thereon) in the United states and/or the WTO country of Israel before March 5, 2003, as evidenced below.

CONCEPTION

3. Before March 5, 2003, we conceived of a refillable fuel cell comprising a casing, a cathode having a first surface and a second surface, at least part of the second surface being exposed to the atmosphere, an anode having a first surface and a second surface, a first chamber configured to retain liquid fuel, wherein the first chamber is defined at least partially by the first surface of the

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anode, and a second chamber configured to retain liquid electrolyte, wherein the second chamber is defined at least partially by the second surface of the anode and the first surface of the cathode, wherein the fuel cell is configured to be sealed in a substantially liquid-tight manner during at least a portion of its service life, and wherein the fuel cell is configured to at least one of receive fresh liquid and discharge spent liquid via at least one resealable opening, as recited in each of claims 1-38.

- 4. Before March 5, 2003, we conceived of a self-contained, refillable fuel cell comprising a cathode having a first surface and a second surface, at least part of the second surface being exposed to the atmosphere, an anode having a first surface and a second surface, a first chamber filled at least partially with a liquid fuel, the first chamber being defined at least partially by the first surface of the anode, a second chamber filled at least partially with a liquid electrolyte, the second chamber being defined at least partially by the second surface of the anode and the first surface of the cathode, at least one sealable opening communicating with the first chamber, at least one other sealable opening communicating with the second chamber, and a cartridge, wherein the fuel cell is configured to at least one of receive fresh liquid and discharge spent liquid from and/or to the cartridge via the sealable openings, as recited in each of claims 39-73.
- 5. Before March 5, 2003, we conceived of a fuel cell system comprising a fuel cell assembly comprising a cathode having a first surface and a second surface, at least part of said second surface being exposed to air, an anode having a first surface and a second surface, a first chamber configured for containing a liquid fuel, said first chamber being defined at least partially by said first surface of said anode, wherein said first chamber has a first liquid transfer port and a second liquid transfer port, said first and second ports being normally closed, a second chamber configured for containing a liquid electrolyte, said second chamber being defined at least partially by

said second surface of said anode and said first surface of said cathode, wherein said second chamber has a third liquid transfer port and a fourth liquid transfer port, said third and said fourth ports being normally closed and a cartridge removably connected to the fuel cell, as recited in each of claims 93-101

- 6. Evidence of such conception as disclosed and recited in claims at least claims 1, 39 and 93 (and those claims dependent thereon) of the application, is shown in the draft application (hereinafter referred to as "the Invention Disclosure") attached hereto as Exhibit A. The Invention Disclosure attached hereto is a photocopy of, and is substantially identical to, an original marked-up draft application prepared and forwarded to patent counsel before March 5, 2003. Drawing substantially similar to the drawings filed in the instant US application were also provided, but are not provided with the attached Invention Disclosure. Applicant notes, however, that certain portions of the marked-up draft application have been blacked-out or redacted.
- 7. The benefits and features of the recited invention are shown and described in the Invention Disclosure (18 pages of specification.

DUE DILIGENCE

- 8. At least Inventor Gennadi Finkelshtain communicated with patent counsel,
 Heribert F. Muenstener, numerous times before March 5, 2003 in preparing a patent application
 based on the Invention Disclosure.
- 9. At least Inventor Gennadi Finkelshtain worked diligently on the preparation of the patent application by first submitting the Invention Disclosure to patent counsel Heribert F.
 Muenstener on a date prior to March 5, 2003.
 - 10. After the invention disclosure was received by patent counsel Heribert F.

Muenstener, at least Inventor Gennadi Finkelshtain worked diligently on the preparation of the patent application with patent counsel Heribert F. Muenstener until a final draft patent application was completed to the satisfaction of the inventors. Communications took place between Gennadi Finkelshtain and Heribert F. Muenstener regarding the draft application during a time period of at least between January 3, 2003 and March 11, 2003, the US filing date of the provisional application No. 60/453,218 of which the instant application claims priority under 35 USC 119(e).

- 11. A final draft of the patent application was forwarded to the Inventors for review on March 10, 2003. The application was approved for filing in the U.S. Patent and Trademark Office on March 11, 2003 and was filed on March 11, 2003.
- 12. We declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further, that the statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Gennadi Finkelshtain

Rami Hashimshony

18.05.2001

Date

Date

16.05.2008

Date

{P25032 00390896.DOC}

EXHIBIT A

APPLICATION FOR PATENT

Inventor:

Genadi Finkelshtain, Mark Estrin, Rami Hashimshony

Title:

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Refillable Fuel Cell System

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a refilling system, in particular, it concerns a refillable liquid fuel cell and a refilling device.

By way of introduction, an electrochemical liquid fuel cell is a device that converts the energy of a chemical reaction into electricity. Among the advantages that fuel cells have over other sources of electrical energy are a high efficiency and environmental friendliness. Although fuel cells are increasingly gaining acceptance as electrical power sources, there are technical difficulties that prevent the widespread use of fuel cells in many applications, especially mobile and portable applications.

A fuel cell produces electricity by bringing a fuel into contact with a catalytic anode while bringing an oxidant into contact with a catalytic cathode. When in contact with the anode, the fuel is oxidized at catalytic centers to produce electrons. The electrons travel from the anode to the cathode through an electrical circuit connecting the electrodes. Simultaneously, the oxidant is catalytically reduced at the cathode, consuming the electrons generated at the anode. Mass balance and charge balance are preserved by the corresponding production of ions at either the cathode or the anode and the diffusion of these

ions to the other electrode through an electrolyte which the electrodes are in contact.

As the fuel cell produces electricity, the liquid fuel and the electrolyte are gradually exhausted of their useful components. After a period of use, the spent liquid fuel and the spent electrolyte need to be removed from the fuel cell and replaced or otherwise the fuel cell needs to be disposed of.

Disposing of the fuel cell is not a preferred option as the relative expensive assembly of the fuel cell makes the price of each cell too high for the fuel cell to be a viable option for many applications.

Refilling the fuel cell presents other difficulties due to hazardous nature of the spent liquid fuel and the spent electrolyte.

There is therefore a need for a refillable liquid fuel cell system.

SUMMARY OF THE INVENTION

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The present invention is a refillable fuel cell system construction and method of operation thereof.

According to the teachings of the present invention there is provided,

[TO BE COPIED IN FROM CLAIMS WHEN FINALIZED]

BRIEF DESCRIPTION OF THE DRAWINGS

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The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is an isometric view of a refillable fuel cell system, having a refillable fuel cell and a refilling device, that is constructed and operable in accordance with a preferred embodiment of the invention;

Fig. 2 is an exploded isometric view of the refillable fuel cell of Fig. 1;

Fig. 3 is a cross-sectional view of the refillable fuel cell of Fig. 1 through a plane which is parallel to lines A-A;

Fig. 4a is an exploded isometric view of a turbulence reducing arrangement of the refillable fuel cell of Fig. 2;



Fig. 5a is an exploded isometric view of the refilling device of Fig. 1;

Fig. 5b is a cross-sectional view of the refilling device of Fig. 1 through a plane which is parallel to lines B-B;

Fig. 6 is an axial sectional view of a valve arrangement, prior to coupling, for use with the refillable fuel cell system of Fig. 1;

Fig. 7 is an axial sectional view of the valve arrangement of Fig. 6 which is partially coupled;

Fig. 8 is an axial sectional view of the valve arrangement of Fig. 6 which is fully coupled;

Fig. 9 is an isometric view of the refillable fuel cell system of Fig. 1 which is interlocked;

Fig. 10 is a cross sectional view, through a plane which is parallel to lines A-A, of the refillable fuel cell system of Fig. 9 prior to refilling the refillable fuel cell;

Fig. 11 is a cross sectional view, through a plane which is parallel to lines A-A, of the refillable fuel cell system of Fig. 9 during refilling the refillable fuel cell; and

Fig. 12 is a cross sectional view, through a plane which is parallel to lines A-A, of the refillable fuel cell system of Fig. 9 after refilling the refillable fuel cell.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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The present invention is a refillable fuel cell system construction and method of operation thereof.

The principles and operation of the refillable fuel cell system according to the present invention may be better understood with reference to the drawings and the accompanying description.

Reference is now made to Fig. 1, which is an isometric view of a refillable fuel cell system 10, having a refillable fuel cell 12 and a refilling device 14, that is constructed and operable in accordance with a preferred embodiment of the invention. As refillable fuel cell 12 produces electricity, the liquid fuel and the electrolyte of refillable fuel cell 12 are gradually exhausted

of their useful components and are defined as spent liquid fuel and spent electrolyte. An example of a preferred fuel is a suspension of NaBH4 in an NaBH₄ saturated KOH solution, as described in co-pending U.S. Application No. 10/230,204, which is incorporated by reference for all purposes as if fully set forth herein. A preferred example of a suitable electrolyte is also KOH solution. The spent liquid fuel and the spent electrolyte are removed from refillable fuel cell 12 and a replacement liquid fuel and a replacement electrolyte are inserted into refillable fuel cell 12 by refilling device 14. In accordance with a most preferred embodiment of the present invention, the spent liquids are removed from refillable fuel cell 12 into refilling device 14 and replacement liquids are inserted by refilling device 14 into refillable fuel cell 12 substantially simultaneously. Moreover, refilling device 14 stores the spent liquids in substantially the same volume that the replacement liquids were stored. However, it should be noted that fuels and electrolyte are still maintained in separate volumes within refilling device 14. In accordance with a first alternate embodiment of the present invention the removal of the spent liquids and the insertion of the replacement liquids are not performed simultaneously. In accordance with a second alternate embodiment of the present invention the refilling device 14 stores the spent liquids and the replacement liquids in separate volumes.

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Reference is now made to Figs. 2 and 3. Fig. 2 is an exploded isometric view of refillable fuel cell 12.

Refillable fuel cell 12 has a fuel cell assembly 16. Fuel cell assembly 16 includes two electrode assemblies 18, which share a common fuel chamber 30. The choice of the number of electrode assemblies and their dimensions are design considerations which depend on the required electrical output, as will be clear to one ordinarily skilled in the art. Fuel cell assembly 16 also includes a bottom housing portion 58, a top housing portion 60, three gas evacuation devices 62, two side casings 64, a central housing portion 68 and a plurality of conductive plates 66.

3, which is a cross-sectional view of refillable fuel cell 12 of Fig. 1 through a plane which is parallel to lines A-A. Each electrode assembly 18 includes a cathode 22 having two surfaces 20, 21. At least 80% of surface 20 is exposed to air. Each electrode assembly 18 also includes an anode 24 having two surfaces 26, 27. Fuel cell assembly 16 also includes two electrolyte chambers 28. Each electrolyte chamber 28 contains an electrolyte and is defined at least partially by bottom housing portion 58, top housing portion 60, surface 21 of cathode 22 and surface 26 of anode 24. Fuel chamber 30, which contains a liquid fuel, is disposed between electrolyte chambers 28. Fuel chamber 30 is defined at least partially by bottom housing portion 58, top housing portion 60, surfaces 27 of anode 24, which faces out of electrode assemblies 18. Fuel chamber 30 has two openings, a lower opening 34 and an upper opening 36. Reference is again made to Fig. 2. Lower opening 34 is provided with a normally-sealed fluid transfer port, exemplified by a valve 38,

and upper opening 36 is provided with a normally-sealed fluid transfer port, exemplified by a valve 40. Valve 38 and valve 40 are normally sealed. Valve 38 is disposed below the fluid level of the liquid fuel in fuel chamber 30. Valve 38 is disposed in the lower section of fuel chamber 30 and valve 40 is disposed in the upper section of fuel chamber 30. This, together with other precautions described below, helps to ensure that, when valve 38 and valve 40 are open and a replacement liquid fuel is introduced into fuel chamber 30 via valve 38 and the existing liquid fuel is removed from fuel chamber 30 via valve 40, the replacement liquid fuel and the existing liquid fuel flow substantially laminarly within fuel chamber 30 which helps reduce mixing of the existing and the replacement liquid fuel. This concept can also be understood by defining the majority of the flow of the existing and replacement liquid fuel flowing through chamber 30 by a plurality of substantially parallel primary flow vectors. The distance between valve 38 and valve 40 measured parallel to the primary flow vectors is equal to the maximum dimension of chamber 30 measured parallel to the primary flow vectors. Fuel cell assembly 16 also includes a turbulence reducing arrangement 50 which further enhances laminar flow, as described above, within fuel chamber 30. Turbulence reducing arrangement 50 will be described below in more detail with reference to Fig. 4a. Electrolyte chamber 28 is generally similar to fuel chamber 30. For example, each electrolyte chamber 28 has two openings, a lower opening 42 and an upper opening 44 (Fig. 3). Lower opening 42 is provided with a valve 46 and upper opening 44 is provided with a valve 48.

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Valve 46 and valve 48 are configured, disposed and perform similar functions to valve 38 and valve 40 of fuel chamber 30, respectively.

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Reference is now made to Fig. 4a, which is an exploded isometric view of turbulence reducing arrangement 50. Turbulence reducing arrangement 50 is disposed within fuel chamber 30,. In the case shown here where filling is from the bottom of the chambers, turbulence reducing arrangement 50 is preferably close to the bottom of the chamber, i.e., near the inlet thereof (see Figs. 2, 3). Turbulence reducing arrangement 50 may be implemented in many ways including, but not limited to, includes a layer of permeable material 52, such as permeable foam, which provides hydraulic damping. By way of a non-limiting example, the permeable foam can be non-woven polypropylene foam with a weight of between 80 and 100 grams per square meter. In the example shown here, layer of permeable material 52 is disposed between two mesh layers 54 which serve to retain layer of permeable material 52. Layer of permeable material 52 and mesh layers 54 are held in place by a frame 56. Turbulence reducing arrangement 50 is disposed horizontally within fuel chamber 30, i.e., substantially perpendicular to the primary direction of fluid flow during refilling. When valve 38 (Fig. 2) and valve 40 (Fig. 2) are open and a replacement liquid is introduced into fuel chamber 30, layer of permeable material 52 helps disperse the replacement liquid fuel which is entering fuel chamber 30 across fuel chamber 30 to promote laminar flow of the replacement liquid fuel. It should be noted that all orientations, for example: bottom, horizontal etc., are used for the sake of brevity assuming the device is standing upright as shown, but, the invention can alternatively be implemented in other orientations.

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Referring briefly to Fig. 4b is a cross sectional view of gas evacuation devices 62 of refillable fuel cell 12 of (Fig. 2). By way of introduction, it will be appreciated that gases accumulate in chamber 30 and chambers 28. These accumulated gases need to be evacuated from refillable fuel cell 12 without allowing any of the hazardous liquids to escape. Therefore, one gas evacuation device 62 is disposed above each of chamber 30 and chambers 28. Gas evacuation device 62 is configured to enable escape of accumulated gas and to prevent escape of liquids. Gas evacuation device 62 may be implemented as any suitable opening or valve which equalizes gas pressure while preferably providing protection against spillage of the liquids within the chambers.

Reference is now made to Fig. 5a, which is an exploded isometric view of refilling device 14. Fig. 5b is a cross-sectional view of the refilling device of Fig. 1 through a plane which is parallel to lines B-B. Refilling device 14 has a

fluid replacement assembly 70. Fluid replacement assembly 70 has a main body 94, a top housing portion 96, a bottom housing portion 98, a front cover 100 and a plurality of sealing gaskets 102. Fluid replacement assembly 70 includes a parallel-walled chamber 72 containing a replacement liquid fuel. Chamber 72 is mainly defined by main body 94, top housing portion 96 and bottom housing portion 98. Chamber 72 has an upper valve 74 and a lower valve 76. Upper valve 74 is configured for coupling with valve 40 (Fig. 2) and lower valve 76 is configured for coupling with valve 38 (Fig. 2). Chamber 72 also includes a fluid flow actuating arrangement 78 which is configured to substantially simultaneously remove the spent liquid fuel from refillable fuel cell 12 via valve 74 and supply the replacement liquid fuel to refillable fuel cell 12 via valve 76. Fluid flow actuating arrangement 78 includes a piston 88 which is configured to move vertically within chamber 72. Upper valve 74 is disposed near the top of chamber 72 and lower valve 76 is disposed near the bottom of chamber 72 such that, when lower valve 76 and upper valve 74 are open, the spent liquid fuel entering chamber 72 via upper valve 74 is kept substantially separate from the replacement fluid exiting chamber 72 via lower valve 76 by piston 88. Piston 88 is spring loaded. Piston 88 also includes a retaining rod 89 which is generally interlocked with a shaped slot in a release bar 92. Retaining rod 89 and release bar 92 are collectively defined as a retaining arrangement. Retaining rod 89 is released by lateral displacement of release bar 92 causing a release of piston 88. A safety lock 90 prevents releasing of piston 88 by accidentally displacing release

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bar 92. Fluid replacement assembly 70 also includes two parallel walled chambers 80 containing a replacement electrolyte. Two chambers 80 are mainly defined by main body 94, top housing portion 96 and bottom housing portion 98. Each chamber 80 has an upper valve 82 and a lower valve 84. Upper valves 82 are configured for coupling with valves 48 (Fig. 2) and lower valves 84 are configured for coupling with valves 46 (Fig. 2). Each chamber 80 also includes a fluid flow actuating arrangement 86 which is configured to substantially simultaneously remove spent electrolyte from refillable fuel cell 12 via valve 82 and supply replacement electrolyte to refillable fuel cell 12 via valve 84. Fluid flow actuating arrangement 86 and upper valve 82 and lower valve 84 are configured substantially the same as the corresponding elements of chamber 72. It will be apparent to those skilled in the art that refilling device 14 can be used to replace other liquids. Additionally, refilling device 14 can be implemented with one or more chambers.

In particularly preferred implementations, refilling device 14 is implemented as a disposable device produced primarily from lightweight low-cost materials. For this reason, at least the main body of the device (main body 94, top housing portion 96 and bottom housing portion 98) are preferably made of polymer materials which are suitable to withstand exposure to the chemicals used. Preferred examples of polymer materials include, but are not limited to, PVC and polyurethane. In practice, substantially all components of the refilling device 14 (other than those with specific mechanical requirements such as springs) are preferably implemented from such polymer materials.

Reference is now made to Figs. 6, 7 and 8. It will be understood that the liquid transfer ports and docking ports of the fuel cell and refilling device respectively are configured to mate in order to allow replacement of the fuel cell liquids, and must re-seal on separation to prevent leakage of the contained liquids from either device. To this end, the preferred features of these ports include reliable non-drip mating and re-sealing, while maximizing flow rates as much as possible when open. It will be understood that any ports which provide these features may be used. Preferred examples include, but are not limited to, mechanically interlocking valves and self-sealing plugs pierced by hollow needles. One particularly preferred implementation will now be exemplified with reference to Figures 6-8.

Fig. 6 is an axial sectional view of a valve arrangement 104, prior to coupling, for use with refillable fuel cell system 10 of Fig. 1. Fig. 7 is an axial sectional view of valve arrangement 104 of Fig. 6 which is partially coupled. Fig. 8 is an axial sectional view of valve arrangement 104 of Fig. 6 which is fully coupled. By way of introduction, the valves, alternatively described as ports, of the present invention and their coupling, alternatively described as docking, are subject to design constraints which include the following factors. First, the dead space between the valves needs to be minimized to prevent hazardous liquids dripping from the exterior of the valves after the liquids have been replaced. Second, other precautions need to be incorporated to prevent dripping. Third, the cross-sectional area of the valves needs to be as large as possible to ensure good flow rates. By way of example, valve arrangement 104

illustrates the coupling of upper valve 74 and valve 40. However, it should be noted that corresponding valves of refillable fuel cell 12 and refilling device 14 are configured to operate in substantially the same way as upper valve 74 and valve 40. Valve 40 includes a plunger 112 having an alignment portion 106. Alignment portion 106 is typically a hollow tube. Valve 40 also includes outer tube 108 having a bore which tapers toward an end 110. Plunger 112 and alignment portion 106 are disposed within outer tube 108, plunger 112 being disposed toward end 110. Alignment portion 106 has one or more holes 114 through the side of alignment portion 106. Alignment portion 106 also tapers toward end 110 to enable liquid to pass through holes 114 when valve 40 is open. It should be noted, that when alignment portion 106 is implemented as a hollow tube, holes 114 are needed. However, if alignment portion 106 is implemented in a different way, such as a X-cross-section tail, holes 114 may not be necessary. An O-ring 116 is disposed between plunger 112 and outer tube 108 to ensure a strong seal of valve 40 when valve 40 is closed. Oring 116 is disposed, as close to end 110 as possible, to minimize any dead space between valve 40 and upper valve 74. Valve 40 also includes a spring 118 and a stop ring 120. Stop ring is mechanically connected to outer tube 108 and spring 118 is disposed between stop ring 120 and the inside of alignment portion 106, such that spring 118 pushes alignment portion 106 and plunger 112 toward end 110 to seal valve 40. Valve 40 also has an O-ring 122 disposed on the outer surface of outer tube 108 toward end 110.

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Upper valve 74 is constructed in substantially the same way as valve 40 except that upper valve 74 does not include O-ring 122. Additionally, upper valve 74 includes a receiving port 124 and an opening pin 126. Receiving port 124 is configured to receive outer tube 108 of valve 40 such that, valve 40 and upper valve 74 are sealably coupled by O-ring 122 being in close contact with receiving port 124, prior to either of valve 40 or upper valve 74 opening (Fig. 7). Opening pin 126 is connected to plunger 112 of upper valve 74 such that, when valve 40 and upper valve 74 are pushed together, opening pin 126 causes valves 40, 74 to open (Fig. 8). Once valves 40, 74 are open, liquid can flow through valves 40, 74 via holes 114 in alignment portion 106.

Reference is now made to Fig. 8. Receiving port 124 includes an absorbent member 128 which is disposed between valve 40 and upper valve 74. Absorbent member 128 is eonfigured deployed to absorb any remaining liquid which is disposed between valve 40 and upper valve 74 after valves 40, 74 are sealed by being pulled apart. Absorbent member 128 has an absorbency capacity with respect to the liquid flowing through valve arrangement 104. For the purpose of the description and claims, the "absorbency capacity" is here defined as the measured with respect to a volume of liquid that can be absorbed by member 128 without dripping. To the extent that the absorbency capacity thus defined varies as a function of the liquid composition, water may arbitrarily be chosen as a reference fluid for the purpose of defining this property. Clearly, however, it is the absorbency with respect to the actual liquid fuel which defines the desired characteristics of the system, as described below.

Preferred types of material for absorbent member 128 are chosen to have properties such that they expands beyond their its-initial volume as they it absorbs liquid, thereby absorbing a volume of liquid greater than the initial external volume of the member. By way of a non-limiting example, absorbent member 128 can be a SIF felt grade hydrophobic foam, which is commercially available from Foamex International (Eddystone, PA). When valves 40, 74 are sealed by being pulled apart, they define a dead space 130 therebetween.

In particularly preferred implementations of the present invention, the absorbent capacity of absorbent member 128 is greater than or equal to the total dead space volume between the valves at the moment of scaling. This arrangement has been found highly effective in Therefore, to preventing spilling any of any the liquid residue trapped between valve 40 and upper-valve 74 after valves 40, 74 are scaled, dead space 130 has a volume which is less than or equal to the absorbency capacity of absorbent member 128. It will be apparent to those skilled in the art that valve arrangement 104 can be used with many applications, especially those applications requiring non-drip valve arrangements with similar design requirements.

Reference is now made to Fig. 9, which is an isometric view of refillable fuel cell system 10 of Fig. 1 which is interlocked. Reference is also now again made to Fig. 1. Refillable fuel cell system 10 has an interlocking

mechanism 132. Interlocking mechanism 132 has a component 134 which is mechanically attached to fuel cell assembly 16 of refillable fuel cell 12 and a component 136 which is mechanically attached to fluid replacement assembly 70 of refilling device 14. To begin removing the spent liquids of refillable fuel cell 12 and to refill refillable fuel cell 12 with replacement liquids, valves 38, 40, 46 and 48 of refillable fuel cell 12 are lined up with corresponding valves 74, 76, 82, 84 of refilling device 14. Refillable fuel cell 12 and refilling device 14 are then pushed together and interlocking mechanism 132 is engaged to maintain the pushing together of valves 38, 40, 46, 48, 74, 76, 82, 84 are now open.

Reference is now made to Figs. 10, which is a cross sectional view, through a plane which is parallel to lines A-A, of fuel chamber 30 and chamber 72 of refillable fuel cell system 10 of Fig. 9 prior to refilling refillable fuel cell 12. Once, valves 38, 40, 74, 76, are open, fuel chamber 30 and chamber 72 define a closed fluid system containing the spent liquid fuel and the replacement liquid fuel, respectively. At this point, piston 88 is at the top of chamber 72. Piston 88 substantially prevents the liquids flowing through valves 38, 40, 74, 76.

Reference is now made to Fig. 11, which is a cross sectional view, through a plane which is parallel to lines A-A, of fuel chamber 30 and chamber 72 of refillable fuel cell system 10 of Fig. 9 during refilling refillable fuel cell 12. Safety lock 90 (Figs. 5a, 5b) is removed from release bar 92 (Figs. 5a, 5b) and then release bar 92 is displaced laterally to release retaining rod 89

thereby releasing spring loaded piston 88. Piston 88 is pushed down through chamber 72 by the spring of piston 88. In this way, piston 88 pushes the replacement liquid fuel out of chamber 72 via lower valve 76 and into fuel chamber 30 via valve 38. The replacement liquid fuel enters fuel chamber 30 via turbulence reducing arrangement 50 which substantially prevents mixing of the spent and the replacement liquid fuels in fuel chamber 30. Substantially simultaneously, piston 88 draws in the spent liquid fuel from fuel chamber 30 via valve 40 of fuel chamber 30 and upper valve 74 of chamber 72. Additionally, the replacement liquid fuel entering fuel chamber 30 pushes the spent liquid fuel upward towards valve 40. Mixing of the spent and replacement liquids is substantially prevented in chamber 72 by piston 88, as described above with reference to Figs. 5a, 5b. It should also be noted that the spent liquid fuel generally has a lower density than the replacement liquid fuel and therefore it may be advantageous for the replacement liquid fuel to enter fuel chamber 30 from the bottom thereof. However, it will be clear to one ordinarily skilled in the art that the invention can be modified such that, the replacement liquid fuel enters fuel chamber 30 from the top thereof and the spent liquid fuel exits chamber 30 from the bottom thereof.

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Fig. 12 is a cross sectional view, through a plane which is parallel to lines A-A, of fuel chamber 30 and chamber 72 of refillable fuel cell system 10 of Fig. 9 after refilling refillable fuel cell 12. Refillable fuel cell 12 now contains the replacement liquid fuel and refilling device 14 now contains the spent liquid fuel. Similarly, the spent electrolyte has been removed from

refillable fuel cell 12 to refilling device 14 and substantially simultaneously, the replacement electrolyte has been inserted into refillable fuel cell 12 from refilling device 14. The replacement of the spent liquid fuel and the spent electrolyte is performed substantially simultaneously.

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It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and sub-combinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the prior art which would occur to persons skilled in the art upon reading the foregoing description.